DOI: 10.1007/s11676-007-0015-y

Influence of soil organic matter contents on soil water characteristics of forests on east slope of Gongga Mountain

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Abstracts: By testing soil organic matter (SOM) contents, soil water contents (SWC) within low suctions, and saturated infiltration rates of samples taken from east slope of Gongga Mountain of China, the enhancive effects of SOM contents on SWC within low suctions and saturated infiltration rates were quantified. The simulated functions might be applied on regional experience forest-hydrology model. The improving function of protecting forest floor and increasing SOM contents on forest ecosystem hydrological effects were also embodied.

Keywords: Gongga Mountain; Soil organic matter content; Soil water content within low suction; Saturated infiltration rate

Introduction

Soil organic matter is the most active components of soil solid phase and hard core of soil structure formation and stabilization. By virtue of improving soil structure and soil colloid to influence the constant and dynamic parameters of soil water, soil organic matter can regulate water movement and enhance soil anti-erodibility (Wang *et al*. 1983; Shi *et al*. 2002; Tisdall *et al*. 1982). However, few studies on the influence of soil organic matter on water characteristics were conducted (Ma 1994; Shan *et al*. 1998). This paper is to analyze the effects of soil organic materials on soil water constants, soil water-holding curve within low suction, and saturated infiltration rate by taking soil samples from forests on east slope of Gongga Mountain, China.

Site description and methods

The study was conducted in Hailuogou (29°3l′03″N–29°38′16″N, 10l°52′49″E–102°07′54″E) of east slope of Gongga Mountain, China, with an altitude of 2 600–3 600 m. Soil parent rocks are quartzite, quartz-mica-schist, stripped griotte of Permian, and parent materials of soils are mainly residual-slope deposits, diluvial deposit, glacial deposit, and glaciofluvial deposit. Cited from observation station at elevation of 3 000 m a.s.l, the climate type is mountainous cold temperature zone with annual average temperature of 4.29°C, annual precipitation of 1 980 mm, and annual average relative humidity of 90%. The vertical zonality of vegetation and soil are visible. Subtropical evergreen broad-leaved forest with dominant species of *Lithocarpus clestocarous* distributes from 1 850 to 2 500 m. Coniferous mixed broad-leaved forest with main components of *Tsuga chinensis*, *Acer*, and *Betula*, distributes from 2 500 to 2 800 m. Subalpine coniferous forest distributes from 2 800 to 3 600 m, with dominant species of *Picea brachytyla* and *Abies fabri*. The brown soil, dark brown soil, and brown coniferous forest soil with common properties of skeletal, thin, and rocky, distribute on 1 700–2 500 m, 2 500–2 900 m, and 2 900–3 600 m respectively.

The soil profiles selected under different forests on basis of natural conditions are *Abies fabri- Rhododendron* mature forest (GG01), *Abies fabri* pure forest (GG02), *Abies fabri- Populus purdomii-Sorbus pohuashanensis- Rhododendron* middle aged forest (GG03), slash with clear cutting (GG04), *Lithocarpus clestocarous-drepanostachyum* broad-leaved forest (GG05), *Picea brachytyla -Tsuga chinensis* over mature forest (GG06), and *Abies fabri- Rhododendron* young forest (GG07). The undisturbed soil samples were collected from different genetic horizons (0-20 or 25 cm, 20 or 25 cm) by cylinder cutting (50 mm in inner diameter and 50 mm in height) to analyze porosity (Soil Science Institute of Chinese Academy of Sciences 1978), soil water holding within low suctions (Zhu 1996), and saturated infiltration rate (Zhang 1986). Other soil samples were taken for organic matter content analysis (Soil Science Institute of Chinese Academy of Sciences 1978). All samples were taken with two repeats, and the averages of measured results were used to calculate and analysis. Based on previous literatures and field survey, the texture of soil is mainly sandy with some gravel and sand.

Result and analysis

Soil organic matter content

The organic matter contents of soil samples are GG01A (122), GG01B (58), GG02A (90), GG03A (56), GG03B (44), GG04A (43), GG05A (61), GG05B (53), GG06A (145), GG06B (101), GG07A (57), with an unit of g·kg^{-1}. The organic matter contents

Foundation project: This research was supported by the Knowledge Innovation Project of Chinese Academy of Sciences (KZCX2-SW-319).

Received: 2006-09-03; Accepted : 2006-12-07

Electronic supplementary material is available in the online version of this article at http://dxdoi.org/10.1007/s11676-007-0015-y

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Responsible editor: Song Funan

of soil samples changes between 43–145 g·kg^{-1}, and the highest contents of soil samples are from surface layer of over mature forest (GG06) and mature forest (GG01), and the smallest contents are from slash with clear cutting (GG04) and subsurface layer of middle aged forest (GG03). The possible reasons are decomposition extent of litter fall, humification or mineralization of decomposed matter, developing time of forest and soil, and landform location, and so on.

Soil water constants, soil water holding curve and mathematic simulation

The soil water constants, such as maximum hygroscopicity, wilting point, capillary suspending water, field capacity, saturated water content, etc, are applied prevalently to reflect soil water form, energy state, and property. In this experiment, only saturated water content, field capacity, non-capacity water contents were measured.

Power function $S = a\theta^{b}$, exponent function $S = ae^{-b}$, and hyperbola function $S = \frac{b}{\theta} - a$ are traditional functions for simulating soil water characteristic curve (Yao *et al*. 1992). Research on soil structure, porosity, and hydraulic using fractal geometry is increasing recently (Alexandra 1998; Gimenez *et al*. 1997; Oleschko 1999; Perfect *et al*. 1995).

Huang *et al*. (2002) deduced that the fractal model of soil water characteristic curve was suited for different soil texture based on Menger structure as follow:

$$\psi = \psi a(\theta / \theta s)^{1/(D-3)}$$

where θs is the saturated water content, Ψ the matric suction, and Ψa is the value of air-entry suction. Comparing with power function $S = a\theta^{b}$, b is equivalent to 1/(D-3).

The saturated water contents, capillary water contents, non-capillary water contents, and water holding within low suction of samples, and simulated power functions are shown in Table 1.

Table 1. Soil water constants and soil water characteristic curve simulation

No.	Capillary water contents (cm^3·cm^{-3} %)	Non-capillary water contents (cm^3·cm^{-3} %)	Saturated water contents (cm^3·cm^{-3} %)	Soil suctions and water holding (Kpa cm^3·cm^{-3} %)					Simulated power functions and fractal dimension		
				10	30	50	70	90	Power function	F	FDw
GG01A	44.3	16.3	60.6	45.8	38.3	34.5	33.3	32.6	$S = (4.8E+17)\theta^{-10.326}$	66.55	2.903
GG01B	42.9	15.3	58.2	43.9	36.4	33.9	32.6	31.7	$S = (1.4E+18)\theta^{-10.706}$	82.66	2.907
GG02A	42.8	14.2	57.0	43.5	37.7	34.5	32.8	31.6	$S = (9.8E+18)\theta^{-11.232}$	70.74	2.911
GG03A	41.5	14.8	56.3	42.6	36.8	33.4	31.1	30.3	$S = (6.1E+17)\theta^{-10.560}$	60.20	2.905
GG03B	38.8	14.1	52.9	39.4	33.7	31.6	30.4	29.7	$S = (8.6E+18)\theta^{-11.465}$	133.02	2.913
GG04A	38.1	12.4	50.5	38.8	32.8	31.2	30.3	29.5	$S = (9.6E+19)\theta^{-12.202}$	109.27	2.918
GG05A	45.1	16.5	61.6	46.7	40.5	36.6	33.7	31.5	$S = (1.4E+17)\theta^{-9.938}$	42.33	2.899
GG05B	43.6	14.3	57.9	44.7	38.8	35.8	33.3	31.1	$S = (2.6E+18)\theta^{-10.820}$	46.42	2.908
GG06A	44.8	16.9	61.7	46.1	38.2	33.7	31.9	30.8	$S = (7.4E+15)\theta^{-9.232}$	50.18	2.892
GG06B	43.2	15.4	58.6	44.8	37.5	34.1	32.2	31.1	$S = (2.5E+17)\theta^{-10.225}$	54.70	2.902
GG07A	41.1	14.1	55.2	42.5	36.3	33.5	32.8	31.1	$S = (1.1E+19)\theta^{-11.345}$	70.99	2.912

Note: $F_{0.01(1,n-2)}$=21.20, *n*=6

Saturated water contents, capillary water contents, and non-capillary water contents separately change in range of 61.7%–50.5%, 45.1%–38.1%, and 16.5%–12.4% (cm^3·cm^{-3}). The most effective simulation function of soil water holding curve within low suction is power function, with all *F* values through significant test at 0.01. The fractal dimension of soil water holding curve based on the method above (Huang *et al*. 2002) is calculated (Table 1), and the correlation coefficients between fractal dimension and soil water content at different suction are –0.904** (saturated), –0.846** (10×10^3 pa), –0.736** (30×10^3 pa), –0.545 (50 ×10^3 pa), –0.409 (70 ×10^3 pa), –0.423 (90 ×10^3 pa), ($r_{0.05(n-2)}$=0.6021, $r_{0.01(n-2)}$=0.7348 n=11), respectively, all of the water contents within low suction are negative correlation with fractal dimensions. The trend of the less of fractal dimension and the larger change of water content within low suction is embodied too. The fractal dimension can be regarded as synthetic index of soil water holding curve.

Relationship between soil organic matter contents and water constants and water holding curve

The correlation coefficients between soil organic matter contents and saturated water contents, capillary water contents, non-capillary water contents, soil water holding at different suctions, are calculated and shown in Table 2.

The correlation coefficients in Table 2 show the promotion effects of soil organic matter content on soil water content properties. Especially, the correlation coefficients between organic matter content and saturated water contents, capillary water contents, non-capillary water contents, water content at suction of 10 Kpa, fractal dimension of soil water holding curve within low suction, all pass the significant test at 0.05. The line regression functions are as follows:

$$Ysat = 0.070X + 52.042 \quad F=7.795$$

$$Ycap = 0.043X + 39.135 \quad F=6.157$$

$$Ynon-cap = 0.027X + 12.907 \quad F=8.535$$

$$Yfd = -0.001X + 2.918 \quad F=10.114$$

($F_{0.05(1,n-2)}$=5.12 $F_{0.01(1,n-2)}$=10.5 6 n=11)

where: $Ysat$, $Ycap$, $Ynon-cap$, Yfd, *X*, are the saturated water contents, capillary water contents, non-capillary water contents, fractal dimension of soil water holding curve within low suction, organic matter contents, respectively.

Table 2. Correlation coefficients between soil organic matter contents and water contents

	Saturated water contents	Capillary water contents	Non-capillary water contents	Water holding at 10 Kpa	Water holding at 30 Kpa	Water holding at 50 Kpa	Water holding at 70 Kpa	Water holding at 90 Kpa	Fractal dimension of water holding curve within low suction
Organic matter contents	0.681*	0.637*	0.698*	0.636*	0.455	0.230	0.286	0.491	-0.727*

Note: $r_{0.05(n-2)}=0.6021$, $r_{0.01(n-2)}=0.7348$, n=11

The soil water holding curve within low suction for the representative soil samples (Fig 1) shows that the whole curve shifts up along with the increase of organic matter contents. This means the more organic matter contents, the more water contents at the same soil water suction. Other research showed that soil water contents mainly rest with capillary and pore-size distribution, and soil structure affects water holding curve at low soil water suction (Zhu 1996; Yao 1992). So, soil organic material can promote soil water contents within low suction by virtue of improving structure to increase porosity, inflecting soil colloid to enhance adsorption (Shan *et al*. 1998).

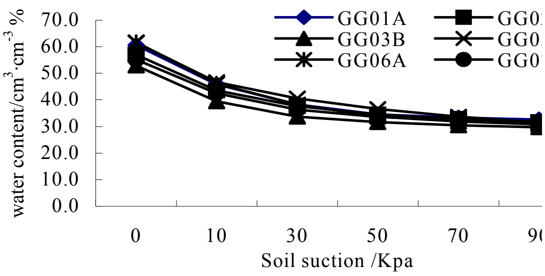

Fig. 1 Representative soil water characteristic curve within low suction

Relationship between organic matter contents and infiltration

At saturated state, the soil hydraulic conductivity can be promoted by the increase of soil porosity especially large pores and the enhancement of connectivity, while the soil hydraulic conductivity can be restrained by soil sorption. Fig. 2 showed that the saturated infiltration rate increases slowly along with the increases of organic matter contents. This result is different from the research of Shan (1998). The reason may rest with the difference between cultivated soil and forest soil, little content of clay for cold climate and slow chemical weathering rate in the studied area in this experiment, and better pore connectivity for much root under forest. The line regression function of soil organic matter contents and saturated infiltration rate through significant test is as follow:

$$Y = 0.013X + 7.665 \qquad F=6.021 \quad r=0.633$$

Where: Y is the saturated infiltration rate (mm·min^{-1}), X is the soil organic matter content (g·kg^{-1}), ($F_{0.05(1,n-2)}=5.12$, n=11).

Conclusion

The experimental results showed that soil organic materials can enhance soil water contents within low suctions and saturated infiltration rates by virtue of improvement of soil structure and increasing porosity. The establishment of quantitative functions can provide a help for the regional experience forest-hydrological model research. For the protection and construction of regional eco-environment, the results indicated that protecting ground layer and increasing soil organic material contents are important to improvement of hydrological effects in forest ecosystem.

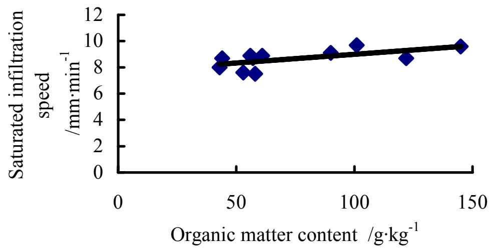

Fig. 2 The fitting curve between soil organic matter content and saturated infiltration speed

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